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(19) (CA) APPLICATION FOR CANADIAN PATENT (12)

(54) Constant Force Gas Spring

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Notice: The specification contained herein as filed

FIELD OF THE INVENTION

This invention relates to a gas spring, and more particularly to a gas spring that provides a constant opposing force over at least a portion of the distance of travel of the gas spring, and a method of manufacturing the gas spring.

BACKGROUND AND SUMMARY OF THE INVENTION

It is known to provide a gas spring with a construction such that the force transmitted by it remains unchanged through at least a portion of its line of travel. This is described by de Callatay, United States patent no. 3,106,388. Such gas springs typically include a primary cylinder and a piston movable within the primary cylinder. A flexible diaphragm is attached to the piston and to the primary cylinder to form an enclosed and sealed chamber. The primary cylinder includes a flared portion dimensioned so that as the volume of the chamber changes, the effective cross-sectional area of the piston and diaphragm combination changes inversely proportionally with the volume.

In such and similar prior art gas springs, the fixed cross-sectional area of the piston was typically large in relation to the effective cross-sectional area of the flexible diaphragm, as shown for example in Bank, United States patent no. 3,078,085 (in which the spring rate increases on compression) and Stengelin, United States patent no. 3,053,528 (which relates mainly to the securing mechanism for a rolling diaphragm).

More recently, gas springs have been provided with central rods which are fixed to the main cylinder and which extend inside a secondary cylinder. The

interior of the secondary cylinder is filled with a hydraulic fluid and used as a hydraulic damper, and may be pressurized as in Keijzer, United States patent no. 3,954,256 or have metered flow of the hydraulic fluid as in Margolis, United States patent no. 4,844,428. These mechanisms control the damping effect of the secondary cylinder. Pryor, United States patent no. 4,555,096 is a more recent example of a device having a central rod and variable spring rate. However, the diaphragm of Pryor appears radially inextensible with the result that the variation of the spring rate cannot be made very high. That is, the effective cross-sectional area of the diaphragm varies very little over the range of travel of the piston. The flaring of the piston (secondary cylinder) either means that the piston must be made large (Figure 2 of Pryor) or there is very little variation of the spring rate (Figure 3 of Pryor).

Prior constant force gas springs such as de Callatay have required primary cylinders with large gas volumes and therefore large cylinders in order to provide a constant force through a reasonable length of travel. This limits their utility. In one aspect, this invention provides a constant force gas spring that assists in reducing the volume of the primary cylinder and hence the gas spring to a useful size while providing a constant force over a long line of travel.

The total force which the gas spring exerts is a result of the high pressure gas acting on the diaphragm and on the secondary cylinder. A small secondary cylinder in cross-section does not affect the difference in pressure as much as a large secondary cylinder, while a large diaphragm is able to compensate for greater

pressure differences. Therefore, in one aspect of the invention, the inventor has proposed to minimize the size of the fixed secondary cylinder cross-section in relation to the diaphragm, so that greater gas pressure differentials may be accommodated over a wide range of movement of the secondary cylinder. With active pressure regulation systems as described in for example Margolis, United States patent no. 4,844,428 or Schultze, United States patent no. 3,046,001 (which shows a manually controlled system), the reduction of the volume of the gas spring allows a smaller amount of gas to be added or exhausted from the gas spring to effect the desired pressure control.

There is therefore provided in accordance with one aspect of the invention an improved gas spring in which a constant force gas spring having a flared primary cylinder includes a secondary cylinder, and a rod extending from the primary cylinder into the secondary cylinder, whereby the secondary cylinder effectively acts as a piston in the primary cylinder in combination with the diaphragm. The fixed effective cross-sectional area of the secondary cylinder is minimized in relation to the effective cross-sectional area of the diaphragm. Since the variation in spring rate is created by the variation in the effective cross-sectional area of the diaphragm, the minimization of the effective cross-sectional area of the secondary cylinder increases the range of variation of the spring rate. Thus, the manufacture of the invention includes the step of minimizing the fixed effective cross-sectional area of the secondary cylinder. By this minimization, the total effective cross-sectional area of the secondary cylinder and diaphragm at full

compression is much lower than the total effective cross-sectional area at full extension.

To achieve minimization of the fixed effective cross-sectional area of the secondary cylinder, the secondary cylinder may have a non-circular, such as elliptical, cross-section, and the central rod in the secondary cylinder may be increased in radius.

In a further embodiment of the invention, the open end of the cylinder may have a compound flare in which a flared section is bordered by first and second sections each having parallel sides.

The gas spring of the invention may be used wherever a shock absorber is required, but is particularly suited for automobiles or other vehicles.

BRIEF DESCRIPTION OF THE DRAWINGS

There will now be described a preferred embodiment of the invention, with reference to the drawings, by way of illustration, in which like numerals denote like elements and in which:

Figure 1 is a section through a first gas spring showing the gas spring fully compressed;

Figure 2 is a section through the gas spring of Figure 1 showing the gas spring fully extended;

Figure 3 is a section through an embodiment of the invention showing a secondary piston with enlarged diameter;

Figure 4 is a section through another embodiment of the invention showing a gas spring having a secondary cylinder with an elliptical section;

Figure 5 is a cross-section through the secondary cylinder shown in Figure 4 along the line 5-5 when the secondary cylinder is fully compressed;

Figure 6 is a cross-section through the secondary cylinder shown in Figure 4 along the line 6-6 when the secondary cylinder is fully extended; and

Figure 7 is a section through yet a further embodiment of the invention showing a primary cylinder with parallel sections on either side of the flared section.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring to Figures 1 and 2, a primary cylinder 12 has an open end 14 and a closed end 16. In the closed end 16 is a port 10 for adding and exhausting gas from the primary cylinder. At the closed end 16 is means 18 for attaching the primary cylinder to a vehicle or other structure requiring suspension. Inside the primary cylinder 12 and extending out through its open end 14 is a hollow piston or secondary cylinder 22 which is movable within the primary cylinder 12 along a line of travel defined by the longitudinal dimension of the secondary cylinder 22. The secondary cylinder 22 terminates in means 19 for connecting the gas spring to a structure, for example, the wheel and axle assembly of a vehicle. The secondary cylinder 22 acts both as a piston and as a secondary cylinder as described in more detail below in relation to Figure 3. A rod 24 is fixed to the closed end 16 of the primary cylinder 12 and extends from the closed end 16 of the primary cylinder into the secondary cylinder 22. The secondary cylinder 22 has a fixed effective cross-sectional area in the line of travel defined by the area of the secondary cylinder facing towards the closed end 16 of the primary cylinder 12. The effective cross-sectional area of the secondary

cylinder 22 as shown in Figure 1 is the area of the annulus defined by the outer wall of the rod 24 and the wall 20 of the secondary cylinder 22.

An annular diaphragm 26 has a first end 29 circumferentially attached and sealed against the secondary cylinder 22, and has a second end 32 circumferentially attached and sealed against the primary cylinder 12 with seals 28 such that the primary cylinder 12, secondary cylinder 22, rod 24 and diaphragm 26 form a sealed chamber 34. The first end 29 of the annular diaphragm 26 is clearly movable in the line of travel of the secondary cylinder 22. The annular diaphragm 26 has a variable effective cross-sectional area in the line of travel of the secondary cylinder 22, which reaches a maximum when the secondary cylinder 22 is fully extended as shown in Figure 2 and a minimum when fully compressed as shown in Figure 1. The maximum effective cross-sectional area is the area of the annulus formed between the end 30 of the flared section and the wall 20 of the secondary cylinder 22. The minimum effective cross-sectional area of the diaphragm 26 is defined by the inner wall of the waist 40 of the primary cylinder 12 and the wall 20 of the secondary cylinder 22. The diaphragm is made of an elastic material such as rubber that is inextensible in its axial direction (as for example might be provided by threads or strands in the rubber that lie parallel to each other along the axis of the diaphragm), but extensible in the circumferential direction (so that the diaphragm is radially extensible). This material has an elastic limit beyond which it deforms plastically and the maximum extension of the diaphragm is limited by this elastic limit.

The total cross-section area of the secondary cylinder and the diaphragm is the sum of the fixed effective cross-sectional area of the secondary cylinder and the effective cross-sectional area of the diaphragm. Thus the total effective cross-sectional area varies from a minimum at full compression to a maximum at full extension.

The open end 14 of the primary cylinder 12 includes a flared section 36, flared in such a manner that the effective area of the diaphragm changes with the volume of the chamber 34 to create a constant opposing force to reduction of the size of the chamber 34 over at least a portion of the travel of the secondary cylinder 22 within the primary cylinder 12. The design of such a flared section is known in the art and need not be further described here. It is taught in the art (see for example United States patent no. 4,555,096 to Pryor) that the secondary cylinder may contain the flared section, or both cylinders may contain complementary flared sections. However, the inventor has found that the use of the flared section on the interior cylinder achieves only a small change in the variation in the spring rate and is not preferred in the operation of the present invention.

The construction of the gas springs shown in Figures 1 and 2 results in the ratio of the fixed effective cross-sectional area of the secondary cylinder to the effective cross-sectional area of the diaphragm being lower than is desirable. The gas spring shown in Figures 1 and 2 shows a practical limit (due to the limitations on the extendability of the diaphragm) on the ratio between the cross-sectional area of the secondary cylinder and the maximum effective cross-sectional area

of the diaphragm, which in this case is believed to be about 1:3.4.

The inventor has found that to reduce the volume of the gas spring to a desirable level, while maintaining a constant spring rate over a desirable length of travel, modifications should be made to the constructions shown in Figures 1 and 2.

Thus, in one aspect of the present invention, the fixed effective cross-sectional area of the secondary cylinder 22 is minimized in relation to the effective cross-sectional area of the diaphragm to obtain increased range of constant force with a small volume. Preferably, the fixed effective cross-sectional area of the secondary cylinder should be less than or equal to the minimum effective cross-sectional area of the diaphragm, while even greater improvements are believed to be attainable with the fixed effective cross-sectional area being less than one-half of the minimum effective cross-sectional area of the diaphragm.

The fixed effective cross-sectional area of the secondary cylinder 22 should be less than about one-seventh of the effective cross-sectional area of the diaphragm at full extension, and this may be obtained by the structures shown in Figures 3, 4, 5, 6 and 7.

As shown diagrammatically in Figure 3 (not to scale), the circumference of the secondary cylinder may be increased, without a corresponding increase in the fixed effective cross-sectional area of the secondary cylinder, by increasing the radius of the rod. By this means the fixed effective cross-sectional area of the secondary cylinder may be made lower than the minimum effective cross-sectional area of the diaphragm. There is

thus shown an enlarged primary cylinder 52 with secondary cylinder 54, rod 56 and flared section 58 constructed in the same manner as the primary cylinder, secondary cylinder and rod of Figures 1 and 2, except that the rod 56 and the secondary cylinder 54 have increased radii. To eliminate the interior 38 of the secondary cylinder 54 as a source of compressive force, the interior 38 of the secondary cylinder 54 has means to allow escape of gas on movement of the secondary cylinder towards the closed end. This means is provided by the channels 62 in the head 64 of the rod 56 and thus the rod 56 itself meets only insignificant opposing force on entry into the interior of the secondary cylinder 54. This means essentially no opposing force is met other than frictional forces. This essentially eliminates the rod as a source of compressive force. Channels 62 may also be used for hydraulic damping.

As shown in Figures 4, 5 and 6, the secondary cylinder 72 may be non-circular or as in this case, elliptical, in cross-section. The primary cylinder is also elliptical in a first section 74 and flares at about 78 to become circular in a second section 76. The diaphragm 78 is itself elliptical and attaches to the elliptical secondary cylinder 72 and to the elliptical section 74 of the primary cylinder. Such a design reduces the area of the secondary cylinder for a given circumference and increases the circumference of the diaphragm for a given area. Since the diaphragm is circumferentially elastic, this increase in the circumference increases the maximum amount to which the diaphragm can stretch, and this increases the effective cross-sectional area of the diaphragm in relation to the

fixed effective cross-section area of the secondary cylinder. This is clearly shown in Figure 6 which shows the maximum effective cross-sectional area of the diaphragm (the shaded area 82) and the fixed effective cross-sectional area of the secondary cylinder (the shaded area 84--the cross-section of the rod has been omitted). The drawing is not to scale but shows the principle of the invention. The circumferential elasticity of the diaphragm allows it to stretch into the circular space defined by the circular section of the primary cylinder, with the result that larger volume changes may be accommodated by the larger area of the diaphragm while the force is maintained constant.

As shown in Figure 7, the open end of a primary cylinder 92 may have a first straight section 94 and a second straight section 96, each having parallel sides, on either side of the flared section 98. The rod, secondary cylinder and diaphragm of Figure 7 are otherwise constructed as shown in Figures 1 and 2. Such a design ensures that at full compression the force transmitted by the gas spring increases, and at full extension decreases.

As shown in Figures 1 and 2, the ratio of fixed effective cross-sectional area to effective cross-sectional area of the diaphragm varies from 1:0.54 at 0% increase of the outer circumference of the diaphragm (full compression), 1:1 at 33% increase, 1:2.6 at 66% increase and to 1:3.4 at 100% increase (maximum effective cross-sectional area). Increases over 100% are believed to be unlikely due to limitations in the elasticity of the diaphragm.

Using the optimizing features of the present invention as shown in Figure 3, 4, 5, 6 and 7, the ratio of the fixed effective cross-sectional area to the effective cross-sectional area of the diaphragm may be made 1:1 at full compression, in which case the ratio at 100% increase will be about 1:7, with ratio of the total cross-sectional area at full compression to the total cross-sectional area at full extension being less than 1:4. This clearly allows for a greater range of volume change, and thus for smaller volumes at full compression. If a secondary cylinder with central rod is used as in Figure 3, then the ratio of the fixed effective cross-sectional area to the effective cross-sectional area of the diaphragm can be made about 1:2 at full compression, and the ratio at 100% increase of the diaphragm circumference will be at least about 1:14. In this case, the ratio of the total cross-sectional area at full compression to the total cross-sectional area at full extension will be less than 1:5.

For the operation of the invention, it will be appreciated that the gas spring may be utilized in an active suspension in which the gas volume in the air spring is varied by adding and exhausting gas from the cylinder. Such a system may be automatic, and respond to variations in the load on the gas spring. Such systems are known in the art and do not need to be described here.

The manner of manufacture of gas spring is generally known in the art and the improvement to the known method of manufacture is to provide the constructions of the invention, which in one aspect includes the step as noted above of minimizing the fixed

effective cross-sectional area of the secondary cylinder in relation to the effective cross-sectional area of the diaphragm. In other aspects the method includes forming the secondary cylinder with a non-circular cross-section, forming the secondary cylinder with an elliptical cross-section, enlarging the rod in relation to the secondary cylinder, allowing escape of gas from the secondary cylinder on movement of the rod into the secondary cylinder so that little or no opposing force is met and forming the main cylinder with a compound flare, with straight sides on either side of the flare. For maximum benefit from the invention, it is desirable to combine the features shown in Figure 3, 4, 5, 6 and 7 in one device.

A person skilled in the art could make immaterial modifications to the invention described and claimed in this patent without departing from the essence of the invention.

I claim:

1. A constant force gas spring for a structure requiring suspension, the spring comprising:

a primary cylinder having an open end and a closed end and having means at the closed end for attaching the primary cylinder to the structure;

a secondary cylinder movable within the cylinder along a line of travel and having a fixed effective cross-sectional area in the line of travel;

a rod fixed to the closed end of the cylinder and extending from the closed end of the primary cylinder into the secondary cylinder;

a radially extensible annular diaphragm having a first end circumferentially attached and sealed against the secondary cylinder, and having a second end circumferentially attached and sealed against the primary cylinder such that the primary cylinder, secondary cylinder, rod and diaphragm form a sealed chamber, the first end of the annular diaphragm thereby being movable in the line of travel of the secondary cylinder, the annular diaphragm having a variable effective cross-sectional area in the line of travel;

one or both of the primary cylinder and the secondary cylinder including a flared section, flared in such a manner that the effective area of the diaphragm changes with the volume of the chamber to create a constant opposing force to reduction of the size of the chamber over at least a portion of the travel of the secondary cylinder within the cylinder.

2. The constant force gas spring of claim 1 in which the fixed effective cross-sectional area of the secondary cylinder is minimized in relation to the effective cross-sectional area of the diaphragm.

3. The constant force gas spring of claim 2 in which only the primary cylinder is flared and the total effective cross-sectional area at full compression is less than the total effective cross-sectional area at full extension.

4. The constant force gas spring of claim 3 in which the ratio of the total effective cross-sectional area at full compression to the total effective cross-sectional area at full extension is less than or equal to 1:4.

5. The constant force gas spring of claim 4 in which the ratio of the fixed effective cross-sectional area to the effective cross-sectional area of the diaphragm at full compression is less than one.

6. The constant force gas spring of claim 5 in which the fixed effective cross-sectional area is less than the effective cross-sectional area of the diaphragm at full compression and less than about one-seventh of the effective cross-sectional area of the diaphragm at full extension.

7. The constant force gas spring of claim 6 in which the ratio of the fixed effective cross-sectional area to the effective cross-sectional area of the

diaphragm at full compression is less than about one-half.

8. The constant force gas spring of claim 3 in which the secondary cylinder has a non-circular cross-section.

9. The constant force gas spring of claim 8 in which the secondary cylinder has an elliptical cross-section.

10. The constant force gas spring of claim 9 in which the primary cylinder has first and second parts, the first part having an elliptical cross-section and the second part having a circular cross-section.

11. The constant force gas spring of claim 3 further comprising the open end of the cylinder having first and second sections each having parallel sides on either side of the flared section.

12. In a method of manufacturing a constant force gas spring in which the gas spring includes:

a primary cylinder having an open end and a closed end and having means at the closed end for attaching the primary cylinder to a structure requiring suspension;

a secondary cylinder movable within the primary cylinder along a line of travel and having a fixed effective cross-sectional area in the line of travel;

a rod fixed to the closed end of the primary cylinder and extending from the closed end of the primary cylinder into the secondary cylinder;

a radially extensible annular diaphragm having a first end circumferentially attached and sealed against the secondary cylinder, and having a second end circumferentially attached and sealed against the primary cylinder such that the primary cylinder, secondary cylinder, rod and diaphragm form a sealed chamber, the first end of the annular diaphragm thereby being movable in the line of travel of the secondary cylinder;

the annular diaphragm having a variable effective cross-sectional area in the line of travel; and

the open end of the primary cylinder including a flared section, flared in such a manner that the effective area of the diaphragm changes with the volume of the chamber to create a constant opposing force to reduction of the size of the chamber over at least a portion of the travel of the secondary cylinder within the primary cylinder;

the improvement comprising the step of minimizing the fixed effective cross-sectional area of the secondary cylinder in relation to the effective cross-sectional area of the diaphragm.

13. In the method of claim 12, the step of minimizing the fixed effective cross-sectional area of the secondary cylinder including the step of reducing the total cross-sectional area of the secondary cylinder and diaphragm at full compression to less than a quarter of the total cross-sectional area of the secondary cylinder and diaphragm at full extension.

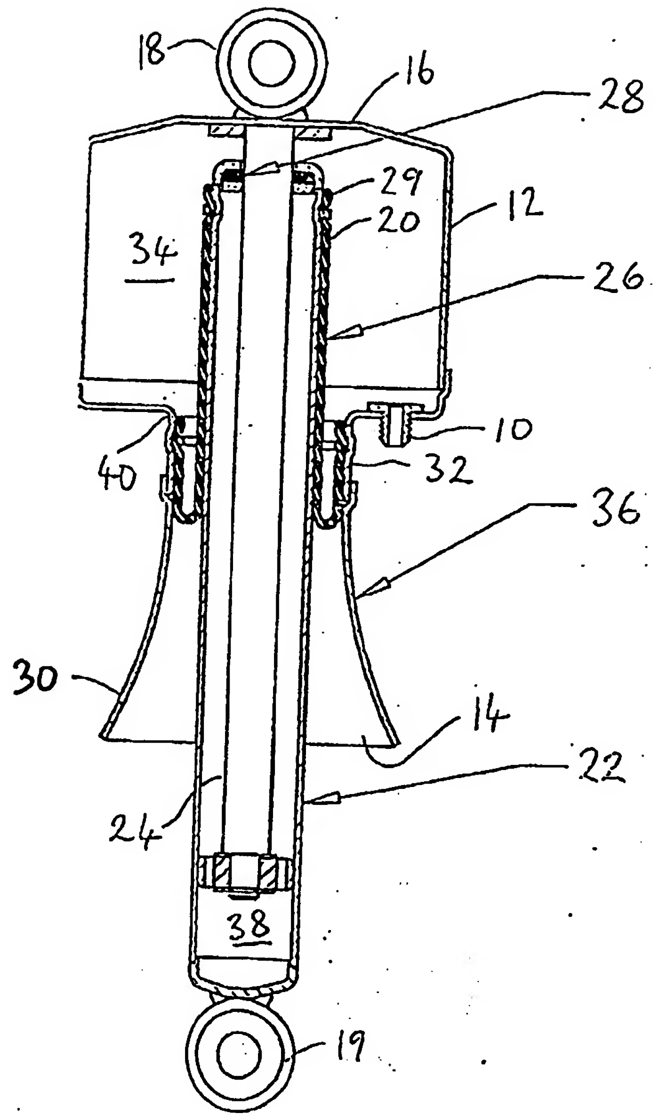

FIGURE #1

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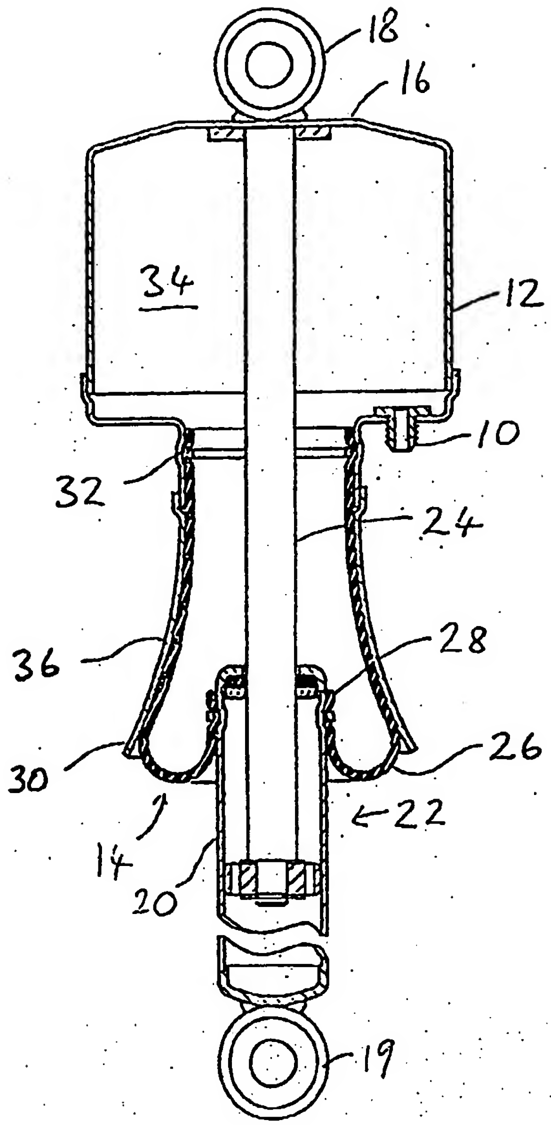

FIGURE #2

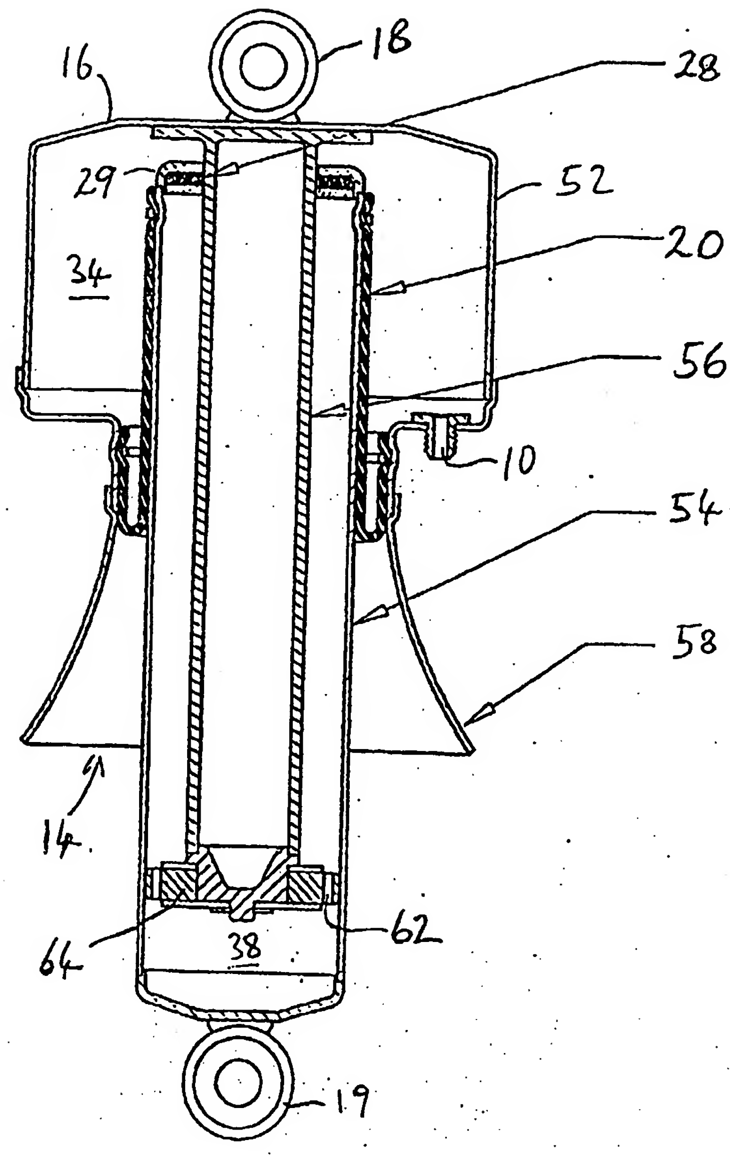

FIGURE #3

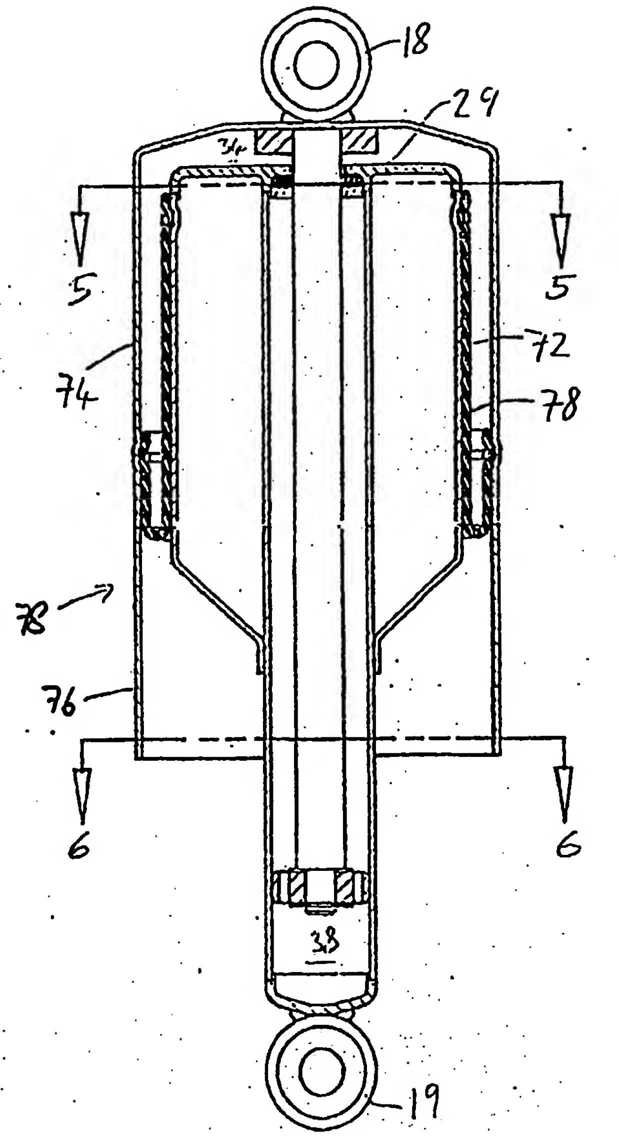

FIGURE # 4 3

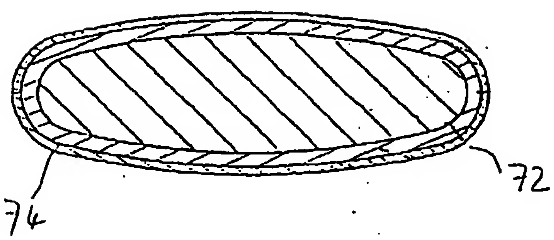

FIGURE # 5

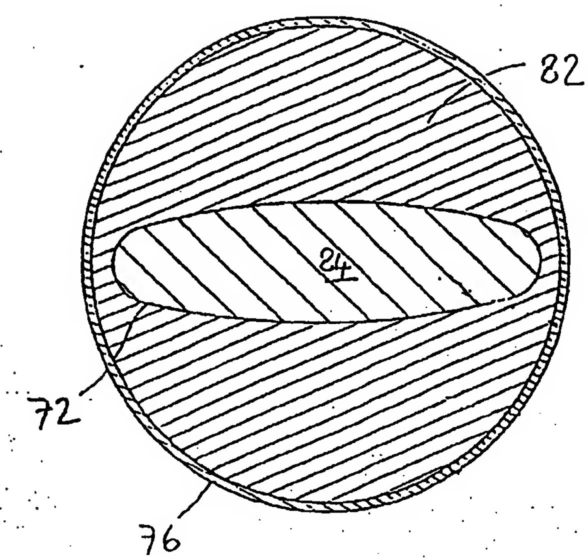

FIGURE # 6

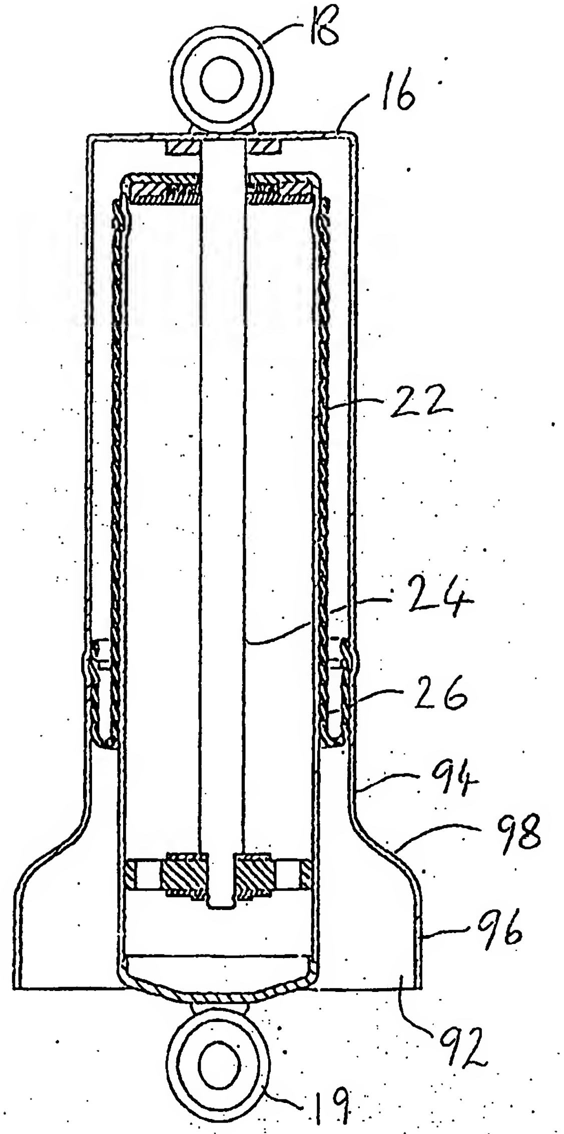

FIGURE #7